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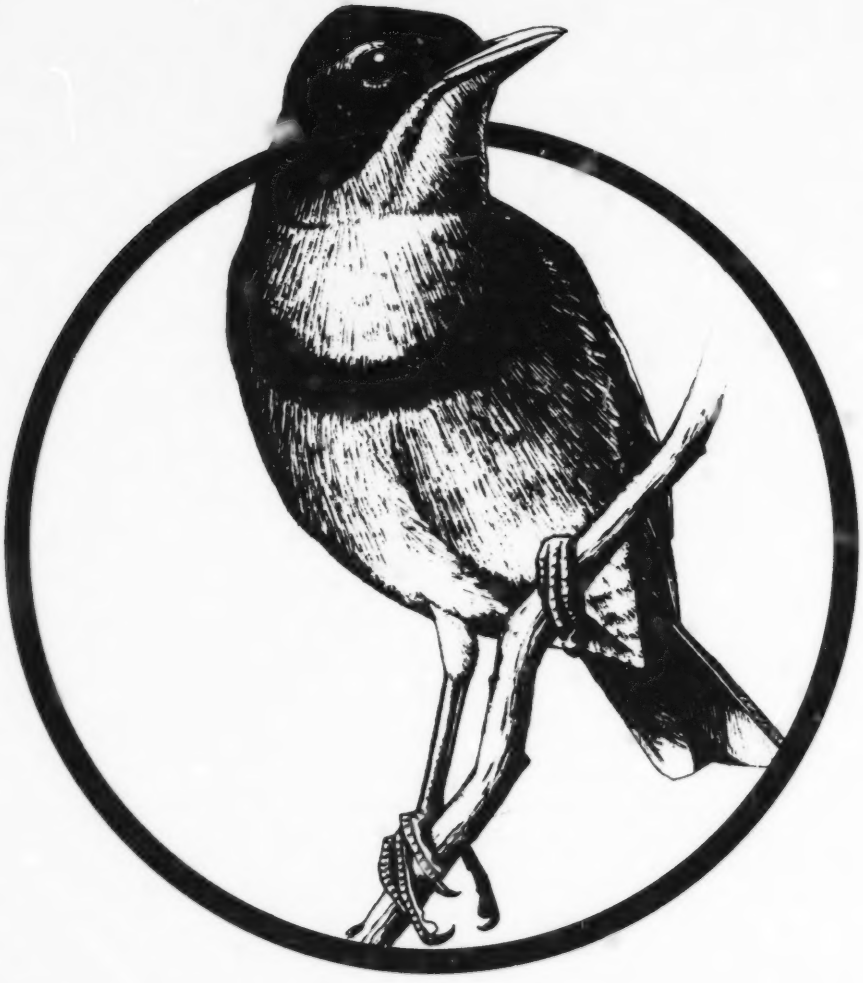
Heritage Record No.1

British Columbia Provincial Museum

MOUNTAINS & SEAS:

Selected Papers from a Conference.



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M O U N T A I N S A N D S E A S

Selected papers from the
Fifth Annual Conference
of the
Canadian Nature Federation
Victoria, British Columbia
June 12/16, 1975

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FOREWORD

This, the fifth of the series of Special Publications of the Canadian Nature Federation, brings together several of the papers presented at the Federation's fifth annual conference held in Victoria, British Columbia, in June, 1975. The Federation deeply appreciates the opportunity it had to come to this beautiful part of Canada to hold this conference and is grateful to the members of the Victoria Natural History Society for their tremendous organizational effort. Federation members from all parts of Canada thoroughly enjoyed the field trips and learned much about British Columbia's natural history at the symposium.

The Federation is particularly grateful for the work of individual organizers, including Mr. Yorke Edwards, chairman of the organizing committee; to Jennifer Fisher, Stephen Mitchell, Ron Muirehead, David Stirling, Harold Hosford, Pat Swift and Roy Wainwright for their work in handling specific aspects of the effort; to Margaret Wainwright for her almost single-handed coordination of the immense and often frustrating task of registrations; and to the many other people who helped these leaders. Honourable mention in this regard must go to Enid Lemon, Wayne Campbell and Jeremy Tatum.

Particular mention should also be made of Keith Taylor whose sensitive sketch of a Varied Thrush became the focus of the conference.

Finally, we acknowledge the generous assistance in several ways, of the Government of British Columbia.

It takes many people, donating much time and energy to put together a conference such as this.

Theodore Mosquin
Executive Director
Canadian Nature Federation

Editor's Introduction

In 1974, the Victoria Natural History Society accepted the Canadian Nature Federation's invitation to sponsor and organize the 5th Annual Convention of the Federation to be held in Victoria the following year. Early in the organizational discussions the problem of a theme came up. Wild Mountains and Fragile Seas was ultimately chosen. It was to be the backdrop against which some of the natural history of British Columbia would be described and some of the conservation problems of Canada's most westerly Province, examined. This book contains a selection of the papers from that Conference.

But describing British Columbia and its natural history is not an easy task. The problem is somewhat analogous to that facing the three blind men in the ancient parable who tried to describe an elephant; what you see depends a lot on where you touch.

On the following pages you will see where four men have touched British Columbia; their personal views, as it were, of parts of the province. Each touches the animal in a separate and somewhat different place. Taken separately and individually, their presentations might conjure up a picture of a rather strange beast - an estuary here, some mountains there, millions of sea-birds and not much connective tissue. Taken together they represent parts - and increasingly important parts - of one of the most complex natural creations on Earth.

But these are more than simple attempts to describe the indescribable; they are also searching examinations of environmental concerns, concerns which reveal a society only just awakening to its responsibilities as custodians, albeit temporary custodians, of this magnificent heritage; a society still comparatively bewildered by the intricate network of conflicting social, economic and environmental values related to these responsibilities; and a society which is becoming increasingly aware that if these conflicting values are to be reconciled their solution lies along the road of reasearch, knowledge and understanding.

Harold Hosford

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WILD MOUNTAINS, FRAGILE SEAS

-an overview of British Columbia

by R. Yorke Edwards, Director
British Columbia Provincial Museum
Victoria

British Columbia is a place of violent topography, but it also has gentle plateaux, and a large area on the Great Plains.

British Columbia is a place of many climates, from desert hot to Arctic cold, from Canada's driest to Canada's wettest.

British Columbia is a place of many faunas and floras. Drive east across British Columbia and you pass through, or near, about seven different life zones. Drive from Calgary to Halifax and you pass through perhaps four life zones.

Here in British Columbia you can stand high on a glacier above alpine tundra growing nothing bigger than dwarf willow, and look down on a low coast growing trees among the world's largest, a coast with winters that some years have no frost at all.

Here you can stand in desert among cactus and greasewood and look into nearby mountain heights above timberline growing caribou and miles of colourful Alpine flowers.

Here you can walk in a day from dawn on a dry plateau with alkali flats, cowboys, and herds of white-faced cattle, to sunset on a coast with some of the richest waters on earth, and with a forest of conifers that is difficult to describe without using rather inaccurate terms like "jungle" and "rain forest".

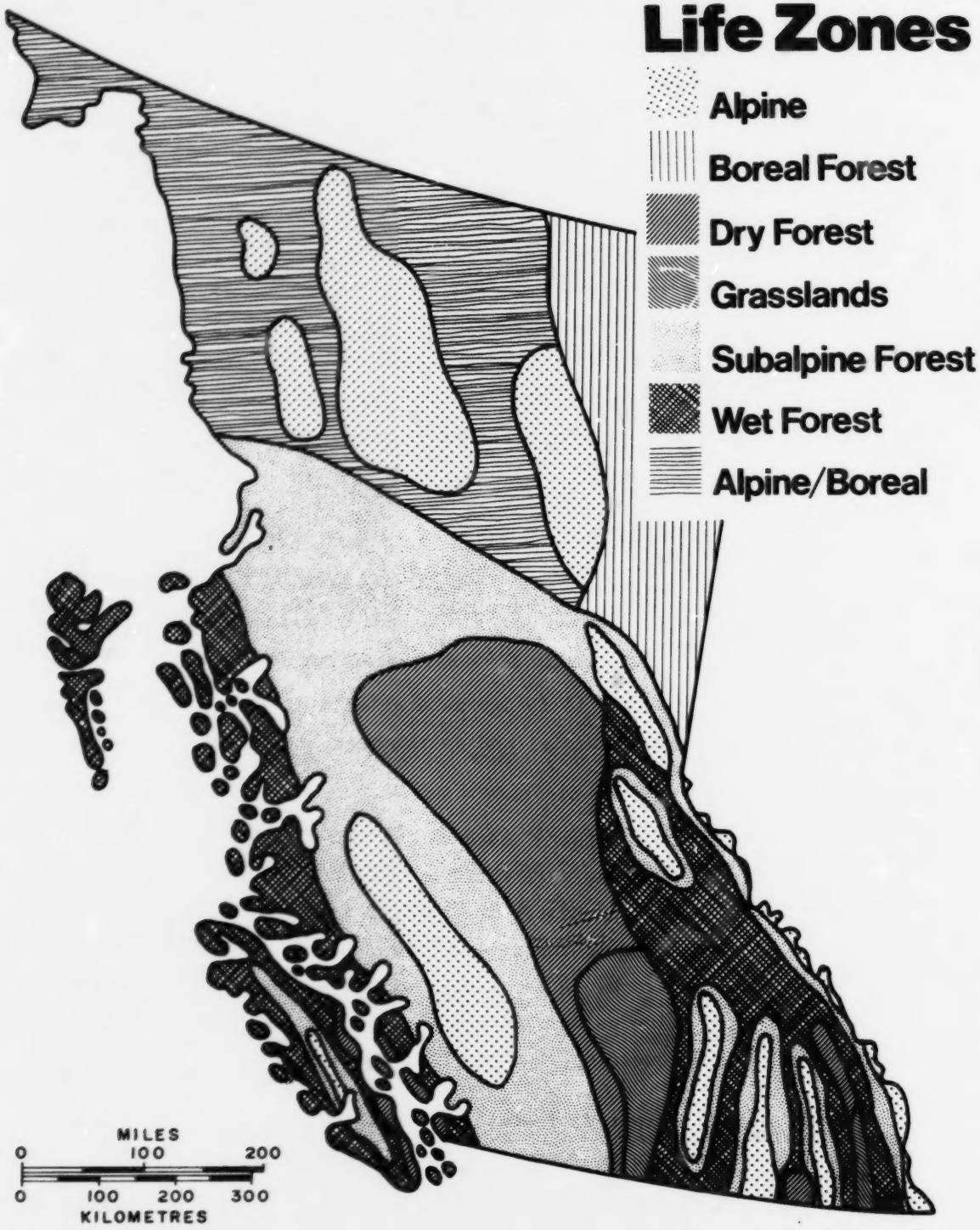
British Columbia is a life-sized demonstration of Earth's geological diversity; and because of the stage that this geology has set, British Columbia is a wild celebration of Earth's fantastic diversity of life.

To understand what kinds of life occur where in British Columbia, the naturalist must carry in his mind a map of its life. Such a map can be only a generalization, really a map of half truths and unavoidable white lies. Over all of these mountains it is a rare square mile that is uniform throughout; changes in elevation, slope, direction of slope, soil, temperature, insolation, moisture, air flow, and other factors result in abrupt changes in vegetation and animal life. Yet a small map must ignore these truths and tell the lie of what seems most important, for the map must be made with a big brush making detail impossible.

More than any other group of Canadians that I can think of, we naturalists are aware of the details - especially the living details - on the surface of Earth. We are aware too, however, that often large areas of Earth's surface are somewhat similar throughout, for they have similar kinds of trees, similar wild flowers, similar birds and spiders and other kinds of life.

If you are a naturalist in Toronto, you know that you live with sugar maples and Blue Jays. You know too that to the north is a land of spruces and Gray Jays, and beyond that again is the Arctic tundra with ptarmigan and dwarf willow. You know that westward are the Prairies with magpies and grasses, while south, along Lake Erie, live sycamores and Orchard Orioles. In short, you know that Canada is a patchwork quilt of life, each patch with plants and animals different from those in neighbouring patches. The first people to see such a patchwork map of nature called each area a life zone. Since then many fancier names have been coined for the same or roughly the same concept, but the term "life zone" remains simple, adequate and meaningful to non-scientists even when the experts are arguing over where the exact edges of the zones may be. So, I am going to introduce you to the life zones of British Columbia.

Let me tell you about my first 24 hours with mountain life zones. My first two glimpses of British Columbia were stunning contrasts. It was 1948 and I was fresh from Toronto, a brand new forester eager to see new trees, new birds, new everything. On a dark wet afternoon the train started down the Pacific slope from Kicking Horse Pass on the Great Divide. The mountain scenery - what I could see of it in the cloud and mist - was stupendous. I can only describe my reaction with the word "awe". But the


Life Zones
Alpine
Boreal Forest
Dry Forest
Grasslands
Subalpine Forest
Wet Forest
Alpine/Boreal
MILES
0
100
200
0
100
200
300
KILOMETRES

dark forest that filed endlessly past had me puzzled, until I realized that the conifer with flat and rather fern-like layers of foliage was western red cedar, related to Ontario's white cedar, and that the big yellow splashes in the spring snow were the western version of skunk cabbage. I was glimpsing North America's wettest kind of place, and I was glimpsing it in a wet mood. Soon night closed down.

In the small hours of the night I blundered from the train at Ashcroft and somehow found a hotel that took me in. There in a place quite unknown to me I was to join a research party. I awoke later to a sunny glow at the window, and looked out sleepily. I can remember my surprise and delight. No trees ! Hills of golden grass, dusty cattle town, forests higher up. Is that a Western Kingbird out there ? Get dressed ! Get into the hills ! And I did. I had awakened in one of the hottest, driest, most deserty parts of Canada.

British Columbia is a place of extremes, and I had just been hit overnight by the contrasts of the soggy wet and the dusty dry. My love affair with the many faces and many moods of British Columbia has been hot and heavy ever since.

The map on page 11 is one naturalist's diagram of the life zones on the face of British Columbia; and do remember, it is a map of half truths and little lies.

Roughly the northern third of the province is a mixture of Boreal Forest, which we can call white spruce country, with Alpine Tundra above the low timberline. Mostly the country is a mix of these two. Only the most extensive areas of tundra are shown, the areas with most high meadows and snow and rock. A large part of northeastern British Columbia is more or less continuous Boreal Forest including the large areas of Great Plains east of the mountains, and the Liard Plain within the mountains.

The Wet Forest dominates low elevations on the wet and mild coast. This is western red cedar and western hemlock country with Steller's Jays, Varied Thrushes and black-tailed deer.

Above this Wet Forest is the coastal version of the cold Subalpine Forest. This is alpine fir country, a forest with Gray Jays and

Hermit Thrushes; on the slopes to the coast this zone has mountain hemlock and yellow cedar which are not found in inland versions of this forest.

Above the Subalpine Forest is Alpine Tundra, ptarmigan country, found on most high mountains but shown here only where high mountains are especially numerous.

Also on the coast is a relatively dry area that usually has a summer drought. This conference is being held in this Dry Forest life zone, an area with Douglas-fir, and in its driest parts with a sort of Douglas-fir - Garry oak savannah with local and scattered arbutus. The map shows this small area around the edges of the Strait of Georgia.

So, to sum up for the north and the coast, there is cold forest, cold tundra, a wet and mild forest, and a dry forest.

To understand the rest, we must first consider local climates. As you cross southern British Columbia, you encounter a series of long mountain masses running roughly north and south. Between them are several deep valleys, also of course north-south oriented.

The movement of air masses across southern British Columbia is mostly from west to east. This air comes laden with moisture from the warm Pacific Ocean. When it encounters a mountain barrier in its way, it rises, it therefore cools, cloud forms, and it may rain - perhaps for days. As the air moves past the barrier it descends, it becomes warmer, clouds often evaporate, and the air may even become thirsty, taking up moisture from the land.

This is why our western slopes of high mountain masses are often cloudy and wet, while the eastern slopes and the deep valleys beyond are dry and basking in the hot sun.

But remember that superimposed on this moisture pattern is a temperature pattern. The mountain heights are cold; mountain valleys are warmer. The highest lands have Alpine Tundra - often mixed with a lot of rather rocky barrens - and this is where Water Pipits and Golden-crowned Sparrows may nest and, in some areas, mountain caribou spend the summer.

Below the tundra is a cold Subalpine Forest with Engelmann spruce and alpine fir. In many respects this is a mountain version of the Boreal Forest, with many plants and animals common to both. Both tend to be a spruce - fir forest and both are cold.

So much for the cold heights. The low valleys and slopes across the southern interior have both wet and dry forests. The Wet Forest in the Interior, much of it in the Columbia River drainage, is shown the same as the Wet Forest on the Coast. These two are much the same, both having much western red cedar and western hemlock, both have Chestnut-backed Chickadees and Steller's Jays, but there are differences too. Western larch is in the Interior version, for instance, but not on the Coast.

The Dry Forest of the Interior also called the Montane Forest, is the realm of Mountain Chickadees, Mountain Bluebirds, Clark's Nutcracker's, Lewis' Woodpeckers, coyotes, mule deer, and many other special creatures living in a world dominated by Douglas-fir and ponderosa pine. The pine, one of our finest trees, is confined to the southern valleys. Douglas-fir goes further north to the central plateau.

Often adjacent to this forest are areas even drier, the Grasslands. Here the hills have lower slopes clothed in yellow bunchgrass, and there is also much grassland savannah where scattered Douglas-firs and ponderosa pine dot the grassy landscape. Here dwell badgers and yellow-bellied marmots, Black-billed Magpies, Long-billed Curlews, Rock Wrens, Poorwills, and other unusual Canadians.

In several places these driest valleys have, at their hottest and lowest places, small areas of desert. These areas, too small to show on the map, are the extreme northern finger-tips of the cool Great Basin Desert that centres about Utah. As anyone who knows deserts might suspect, these lands are alive with many plants and animals, like prickly pear cactus, bitteroot, greasewood, Canyon Wren, white-tailed jackrabbit, harvest mouse, scorpion, and a number of these are found only in such small parts of extreme southern Canada. Canada has desert, but only in small bits that project a few miles north of the 49th parallel.

There quickly, is the pattern of life in this mountain province. Before we leave the mountains there are some points worth emphasis. Notice

that of the dry valleys across the south, one is on the coast. It is flooded by the sea, but it remains our first dry valley inland from the ocean, sunny and fairly dry because it is in the lee of mountains. Notice also that much of southern British Columbia has both an upper and lower timberline. Above is a cold timberline at the Tundra, below is a dry timberline at the Grassland.

Look again at the map to fix it in your mind. And remember that this is a diagram. A number of maps are available that are much more accurate. *

So much for wild mountains, now down to the fragile sea.

The sea that pounds these shores is exceedingly rich. It supplied abundance to the Indians beside it and gave them time to evolve a culture now famous for its unique forms of art. It has been said of these shores that, before Europeans came, they supported the densest population known of non-agricultural people. Whenever the tide went out it exposed a table set with abundance. There were also fish -- halibut, herring, oolichan, and salmon -- especially salmon -- which filled the rivers every year, and which were easily caught, easily dried, easily kept to feed the winter social gatherings of a complex society. And for some, there were even whales hunted at sea in canoes, as well as sea lions, fur seals, harbour seals, and sea otter.

Some say, now, that the sea is the last frontier. Certainly it is one of the last. It will soon be tamed at the present rate of its invasion, tamed, and changed, exploited and impoverished biologically. It is just a repeat, it seems, of a hundred other frontier stories, some history,

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* ROWE, J.S. 1959 Forest Regions of Canada
Dept. of N. Affairs & Natural Resources, Ottawa
Forestry Branch Bull. 123:1-71. Map.

CHAPMAN, J.D. & D.B. Turner. Eds. 1956 British Columbia Atlas of Resources, B.C. Natural Resources Conference, Victoria
48 Maps (No. 11 is Biotic Regions)

KRAJINA, V. 1974? Biogeoclimatic Zones of British Columbia.
Consists of map only. Dept. of Lands, Forests & Water Resources, Government of British Columbia, Victoria.

some now on stage, a few of the last just being planned. Already in the sea, fishing of alarming sophistication has many species decreasing; whaling has several species all but gone. Around the world the sea is man's garbage dump, his sewage sump, and his chemical sink for countless wastes, many unknown in nature and with unknown effects on the living sea. Recreation has discovered the sea. "Recreation", ten years ago one of the "good kinds" of land use and now known as a dangerous destroyer of landscapes, has for years populated the surface of the sea with boats, but now the depths too can be crowded. Diving is now the recreation of the layman. Man the lover of beauty, man the discoverer of nature's secrets, man the connoiseur of art and science, now shares the shallow depths (which incidentally are the most important depths) with man the collector, man the hunter, man the plunderer, and man the vandal. Now almost upon us is man the sea miner, about to use sophisticated machinery to sift mineral nodules from sea floors around the world. One wonders what contribution this will make toward making the sea less alive.

And then there is oil. The waters of British Columbia, famous for their treachery with shipping, are about to become a lane for supertanker traffic bringing oil from Alaska to the United States. When these American ships soon begin to bring the Alaska crude to American refineries in or near Puget Sound, they will endanger almost exclusively Canadian waters, Canadian shores, Canadian sea life. The ships will be huge, perhaps even as big as one million tons and almost a third of a mile long. Even the "small" supertankers of today (up to "only" 500,000 tons), if we can believe reports, * are dangerously designed, poorly made, difficult to steer, often manned by substandard mariners who are unable to see where the ship is going, and at 16 knots today's ships cannot stop within three miles. To add to these hazards, oil is by far the most abundant commodity carried at sea today.

As a biologist, I am concerned that oil spills at sea are popularly regarded as simply messy. I hope that is all they are. I wonder what it does to plankton, to whales, to salmon, to sea otter, to crabs, to squid, and on and on. As was perhaps inevitable, progress is now finding these rich and lovely waters, and as seems equally inevitable, the approach

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*See: Superspill by Becker & Coburn, 1974, Madrona Press, Seattle and Supership by Mostert, 1974, Random House, N.Y.

is "the environment first, but first of all the economy". Not much has changed for all our environmental awareness.

The fragile sea is our next conquest; this time there are no excuses, for now we know the price of tampering with ecosystems that we do not understand, and it is the side effects that seem to get us in the end. Remember the unexpected in DDT, in mercury, in strip mining, in atom blasts, and on, and on, and on. I hope that we have begun to learn the obvious lesson. But in the end the sea must become just another food factory if the world has too many people.

No account of the sea seems complete without whales, and unless I comment on them this conference seems in danger of ignoring them. We have whales. The large ones seem to be scarce, however, because Canada's shore stations for whaling no longer function; the harvest was not of economic size.

The most common species in catches through the 50's and 60's were sperm whales, finback whales, and sei whales, in that order. Presumably they are still out there in numbers. Small numbers of blue whales and humpback whales were also taken. These five species are the only ones of note in the record of Canadian whaling in the Pacific during this century. From 1924 to 1967, four right whales were harpooned (probably by accident) for Canadian shore stations. This species, formerly abundant, was almost eliminated by American whalers throughout the world in the latter half of the last century.

Three smaller species - never much harvested by Canadians - are still numerous: Gray Whale, Minke Whale and Killer Whale. There are also about a dozen kinds of small porpoises and dolphins known from Canada's Pacific waters.

To give some idea of the extent of whaling in our waters, the total numbers of all species taken by Canada from 1905 to 1967 was close to 24,000.

Some of this catch was recorded by species: these were, in order of numbers taken: *

	Approximate Number	Percent
Sperm Whale	7,000	37
Finback	5,700	30
Sei	3,500	19
Humpback	2,000	11
Blue	500	3
Right	4	trace

So there is a glimpse of the mountains and the sea. But dreary speeches cannot do justice to what is out there to be seen. I hope that because of this conference you have time to see some of this land and sea. It's all out there, waiting. And if you come from another province, a lot of it won't look much like home. Good luck, and may you see much that you never saw before of these wild mountains and these fragile seas.

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* Most whale data used in this paper were taken from

Marine Mammals of British Columbia by Pike & MacAskie, 1969
Fisheries Res. Bd. Bull. 171 Ottawa

THE NATURE OF BRITISH COLUMBIA'S FORESTS

R.G. McMinn, Ph.D., Research Scientist

Pacific Forest Research Centre, Victoria

How does one describe the forests of a province that covers nearly 95 million hectares (366,255 sq mi); a province that stretches from south of the 49th parallel to 60° North; a province that reaches from the Pacific Ocean to east of the Rocky Mountains ? When elevations run from tidewater to 3000-metre (9,000 ft) peaks, when climates go from Mediterranean to Arctic/Alpine, and when soils range from heavy clay to bare rock, one can expect the forests of British Columbia to be vast and varied.

BIOGEOCLIMATIC ZONES

The system of Biogeoclimatic Zones [1], developed by Dr. V.J. Krajina of the University of British Columbia, provides a convenient framework for visualizing the regional distribution of forests in British Columbia. A Biogeoclimatic Zone is an area with distinctive regional climate which, in turn, results in distinctive soils and vegetation. In each of the ten forested Zones a few tree species are predominant in mature forests. Although younger forests may be composed of different species, left undisturbed for centuries each type of regional climate ultimately favours only certain types of trees.

Regional Climates

Since regional climate is a major determinant of forest type, an overview of climatic patterns is a good place to start a description of British Columbia's forests.

Rainfall is high throughout most of coastal British Columbia because prevailing westerly winds bring moisture-laden air masses from the Pacific Ocean onto a mountainous coast. Since cool air carries less moisture than warm air, precipitation occurs as these air masses cool in their forced ascent of coastal mountains. Heavy rains fall at sea level and, in winter, deep snow covers the mountains. Prince Rupert, at sea level, averages

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1 A coloured map of Biogeoclimatic Zones, published by the British Columbia Ecological Reserves Committee, may be obtained from B.C. Government Map and Air Photo Sales, 553 Superior Street, Victoria, B.C.

2500 ml (97 in.) of precipitation a year, 2300 ml (93 in.) of which falls as rain. On Hollyburn Ridge, 1000 m (3,100 ft) above Vancouver, precipitation averages 2,880 ml (114 in.), 7.6 m[2] (25 ft) being snow.

East of the Coast Mountains, rainshadows occur because air masses warm as they descend. Ashcroft, for example, records only 190 ml (7.7 in.) of precipitation. Such low amounts, coupled with high summer temperatures, provide insufficient moisture for tree growth. Grass and sagebrush cover the landscape. Trees are not general in the southern Interior until precipitation exceeds 250 ml (10 in.) a year and even then forests resemble open parkland.

Growing seasons are long at tidewater. Higher up mountain slopes, and in northern British Columbia, forest growth is limited by low temperatures and short growing seasons. Growing seasons in the Interior are shorter than on the Coast.

Forested Zones

The *Coastal Douglas-fir Zone* occupies portions of the Coast where rainfall is moderate, 1000 ml (40 in.) or less per year, and summer temperatures are warm. The coppery-red bark of arbutus, a broadleaf evergreen with leathery leaves that is common in warmer parts of the Zone, provides a touch of colour in keeping with the Mediterranean-type climate of southeastern Vancouver Island, the Gulf Islands and the adjacent coastal mainland. In the driest parts of the *Coastal Douglas-fir Zone*, flowering bulbs form natural spring gardens beneath twisted branches of Garry oak. Although veteran Douglas-firs reach considerable size even in dry parts of the *Coastal Douglas-fir Zone*, the giant trees which first brought world markets for British Columbia lumber grow where rainfall is higher.

With increasing rainfall the proportion of western hemlock at lower elevations in Coast forests, rises until hemlock becomes the predominant tree in the *Coastal Western Hemlock Zone* of northern Vancouver Island, the Island's west coast and the coastal mainland of British Columbia.

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2 Since, on the average, 10 ml of snow contains only 1 ml of water, 7.6 m of snow equals 760 ml (30 in.) of precipitation, much more than the 200 ml (4 in.) received by Prince Rupert in the form of snow.

Close to the sea, and on some fertile coastal valley floors, large Sitka spruce (Fig. 1) grow in lichen-draped rainforests. Shrub layers, often reaching shoulder height, may include devil's club always ready to bring discomfort to those unwary enough to clutch its spiny stems.

At higher elevations on the Coast western hemlock gives way to mountain hemlock and amabilis fir, the main trees of the *Subalpine Mountain Hemlock Zone*. Seedlings of these species withstand the high snowfalls characteristic of coastal mountains. Deep snow may, in fact, be necessary to protect young trees from winter cold during their sensitive seedling stage. Engelmann spruce and alpine fir are species better adapted to the extreme cold of mountain slopes east of the Coast Mountains in the *Interior Subalpine Engelmann Spruce - Subalpine Fir Zone*. Natural selection has provided these species with slender spire-like crowns (Fig. 2) adapted to shedding winter snow that might otherwise strip branches and break down bushier tops.

In the southern Interior, orange-barked ponderosa pine forms an open forest type in the *Ponderosa Pine - Bunchgrass Zone* (Fig. 3), the driest climate of any Zone in British Columbia supporting tree growth. A ground cover of grasses provides grazing for cattle. Where rainfall is a little higher, Douglas-fir replaces ponderosa pine, and shrubs as well as grasses are found beneath trees in the *Interior Douglas-fir Zone*. Still more rainfall provides conditions suitable for western hemlock and western red cedar, the main species of mature forests in the *Interior Western Hemlock Zone*. Veteran hemlock trees 130 cm (4 ft) or more through the butt are common. Unfortunately, long before most trees reach this size their heart wood has decayed leaving boles with little value for lumber. They are used for pulp although the forest industry finds such hollow trees expensive to transport, even to a pulp mill.

Because prevailing winds coming from the west move air masses over a series of north-south mountain ranges set at right angles to their path, the southern Interior of British Columbia provides a setting for an alternating succession of forest types from west to east. The *Ponderosa Pine Zone* and the *Interior Douglas-fir Zone* appear in rainshadow areas such as the Okanagan Valley. They are absent from wetter areas, like the

Fig. 1. Sitka spruce and hemlock on alluvial terrace near the Nass River in British Columbia's northwest. Devil's club is common in shrub layers in such forests.

Fig. 2. Slender crowns of alpine fir near timberline are adapted to heavy snowfalls common on mountains in the Interior of British Columbia. Flower-studded alpine meadows occupy areas where deep snows last well into summer and soils are too wet for trees to thrive.

Fig. 3. Ponderosa pine in open stand with bunch grass forming the ground cover in the dry southern Interior of British Columbia.

Fig. 4. Bulbous-topped black spruce grow in peaty soils in the cool climate of northern British Columbia. White flowered labrador tea is a common shrub in such soils.

Columbia River Valley which provides a suitable environment for the *Interior Hemlock Zone*. The *Interior Douglas-fir Zone* reappears in the dry East Kootenays and Rocky Mountain Trench. The intervening succession of ridges is occupied by the *Subalpine Engelmann Spruce Zone* at elevations above 1300 m (4,000 ft).

The *Caribou Aspen - Lodgepole Pine - Douglas-fir Zone* covers broad expanses of the Central Interior Plateau. Aspen and lodgepole pine are the most prevalent trees because these species are especially adapted to regenerating after forest fires. Lightening storms caused extensive fires in the *Caribou Aspen Zone* prior to the introduction of effective methods of fighting forest fires. Understorey grasses and shrubs provide grazing and browse for cattle and wildlife so that ranching vies with logging as mainstay of the economy. Tree growth in fact is slow because the climate is relatively dry and growing seasons are short. Douglas-fir is commonly mixed with aspen and lodgepole pine. It grows in pure stands only when forests have been undisturbed by fire for long periods, allowing time for shorter-lived aspen and lodgepole pine to die out. The frequency of aspen and lodgepole pine in the *Caribou Aspen Zone* differentiates it from the *Interior Douglas-fir Zone*, which has a warmer climate.

Black spruce, a tree with a characteristic tufted top (Fig. 4), is the typical species of the northern *Boreal White and Black Spruce Zone*. Poor drainage and cool temperatures during most of the year encourage formation of peat even on upland soils. Black spruce is at home in peat although its growth is stunted in bogs, something with which the area abounds. White spruce does not tolerate bogs. It grows best in the fresh alluvial soils of river terraces.

In the *Sub-Boreal Spruce Zone*, white spruce trees reach substantial size, reflecting a growing season longer than that of the more northerly *Boreal Spruce Zone*. Alpine fir is a constant associate of white spruce in the *Sub-Boreal Zone*. Unlike white spruce, alpine fir extends from valley floor to timberline. Above 1000 m (3,000 ft), white spruce merges with Engelmann spruce, the distinctive tree of the *Subalpine Zone*. At lower elevations in the *Sub-Boreal Zone*, extensive areas of fertile soil are populated by prickly devil's club which, as on the Coast, indicates productive forest land.

FOREST ASSOCIATIONS

Although one or two species of tree may characterize the extensive areas covered by a single Biogeoclimatic Zone, differences in tree size and changes in the kind of undergrowth plants reveal that the forests of a Zone are far from uniform. Local differences in climate and in soil moisture, fertility and texture may all contribute to the differentiation of various Forest Associations within a Zone.

The sequence of Forest Association on a slope within the *Douglas-fir Zone* on Vancouver Island demonstrates the diversity possible within a single Zone (Fig. 5). On ridgetops, where the availability of soil moisture is limited during the summer by shallow and coarse-textured soil; even mature trees reach little more than 25 m (80 ft) in height and the salal of the shrub layers is coarse and stunted. Lichens grow in openings between shrubs, especially where rock is exposed. Farther downslope, deeper soils store more moisture for tree growth allowing mature trees to exceed 45 m (140 ft) in height. Shrub layers of salal are dense and one metre (3 ft) or more in height. No lichens are found on the ground. Still further downslope the influence of water seeping through finer-textured soil is apparent from tree growth. Veteran trees in soil moistened throughout the growing season reach 75 m (225 ft). The luxuriance of swordfern shows that seepage moisture containing nutrients leached from upslope soils augments soil fertility of lower slopes. Where seepage moisture reaches the surface of muck soils on nearly level ground, skunk cabbage flourishes and western red cedar replaces Douglas-fir as the dominant tree.

Similar variations, too numerous to outline here, occur in all the Biogeoclimatic Zones of British Columbia. The forests of British Columbia may consequently be described as a vast mosaic with numerous local climate and soil factors causing differences from place to place, often within a few metres of each other.

OTHER INFLUENCES

Although climate, local as well as regional, and soil factors such as depth, fertility, and water-holding capacity, are major determinants of the nature of British Columbia's forests, other influences may also have major effects. Fire, insects and diseases are all significant too. Human

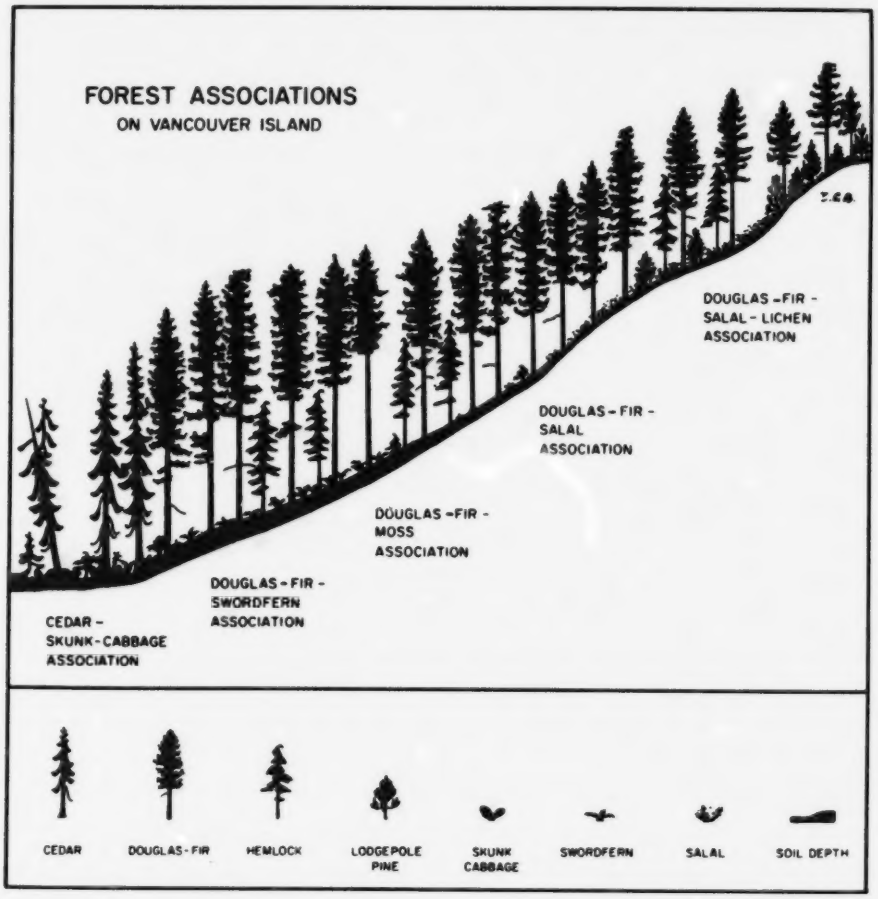

Fig. 5. Schematic diagram illustrating sequence of forest associations on mountain slopes in the *Douglas-fir Zone* on Vancouver Island. Trees on upper slopes are stunted; midslope trees are taller. Giant Douglas-fir occur in "old-growth" forests toward the base of slopes covered by luxuriant swordfern. Cedar and skunk cabbage are found where seepage water trickles through much soils on nearly level ground.

influences are also assuming an increasingly important role. How the forest and mining industries, agricultural land clearing, road building, urbanization and even reservation for park use affect the forests of British Columbia will not be described here because enumeration of such influences would form a complete chapter of its own.

Fire

Fire was a natural factor affecting the composition and appearance of western forests long before man arrived on the scene. Especially in the Interior, lightening storms in summer, when forests were dry, started fires that removed existing tree cover, sometimes over many square miles. In areas where fires were prevalent, species that were adapted to its recurrence fared better than those less well-attuned to fire. Forests in such areas are frequently composed of different species than would have been the case had climate or soil been the main influential factors.

Adaptions to mitigate the destructive effects of fire take many forms. Some species, growing in areas where fire is prevalent, have very thick bark which protects inner tissues. Mature, thick-barked ponderosa pine and Douglas-fir in the dry Interior were largely immune to damage from grass fires which repeatedly swirled about their boles. Even on the Coast, veteran Douglas-firs may show scars of recurrent fires that swept by them during a thousand-year life span.

Veteran trees with branches high up on thick-barked boles provide seed for new forests when more susceptible smaller trees around them perish. Thin-barked trees such as hemlock, on the other hand, flourish in wet climates where fires are centuries apart. Such trees may be more restricted than climate alone would dictate in areas such as the east side of Vancouver Island where fires occur during periodic, unusually long, dry summers.

Lodgepole pine does not have thick bark to save standing trees from destruction by fire. Its adaptation is cones which await the heat of a forest fire to open them. Although fire running through stands of lodgepole pine kills trees, it also releases seed that has been "stored" in unopened cones still retained in tree crowns. A copious shower of seed following fire ensures perpetuation of the species. Lodgepole pine contrasts

with other conifers which have seed crops only at intervals several years apart. Such crops may not coincide with a need for seed to start new trees because the existing forest had been destroyed by fire. Many deciduous trees, for example birch, produce plentiful seed crops nearly every year. Being small and light, birch seed is carried long distances by wind. Consequently, even though both trees and seed may be destroyed within an area affected by fire, fresh seed comes from plentiful crops on trees often some distance from burned areas.

Aspens accommodate to fire not by producing large quantities of seed but by their ability to form suckers. Roots in soils warmed by the sun, because tree canopies have been removed, grow suckers that quickly develop into new trees. Groves of aspen (Fig. 6) soon regenerate after fire has destroyed the former stand because aspen is largely independent of the often precarious process of developing new plants from seed.

Another requisite for contending with fire is seedlings that can withstand the harsh climate of exposed, burned-over areas. Fresh burns with no sheltering trees or lesser vegetation may be hot and dry during the summer and cold in winter. Douglas-fir on the Coast and white pine in the Interior may "encroach" after fire into areas in which hemlock would grow if climate and soil were the only influences. Douglas-fir and white pine seedlings thrive when exposed to the sun, a condition generally unfavourable for hemlock seedlings which are intolerant of heat and dryness. Hemlock seedlings, on the other hand, can grow in the dim light reaching forest floors beneath dense tree canopies. Such conditions are not bright and warm enough for Douglas-fir and white pine. Consequently, although these species are prevalent in young stands, they are replaced by hemlock as forests mature to conditions reflecting the regional climate, unless fire again intervenes to re-establish Douglas-fir or white pine.

Insects

Destruction of trees by insects can be either wholesale or retail. Trees may be killed over many square miles or they may die one at a time. In some cases, changes in the nature of forests may be sudden, almost dramatic; in others, more subtle and harder to perceive.

Mountain pine beetle is an insect that brings about striking

Fig. 6. Aspen-covered slopes are common in the West Kootenays. Such pioneer species replace mature hemlock forests following fire. In the late 1800's, prospectors burned off many miles of forest because trees made mineral strikes more difficult to find. Now mine buildings are deserted with exhaustion of nearby lead and zinc ores.

Fig. 7. The roots of this white pine were decayed by Armillaria root rot until so few were left that wind toppled the tree. Bark beetles commonly breed in dying trees which may then become the source of a new infestation capable of destroying scores more trees.

changes. Its larvae burrow beneath the bark of white and lodgepole pine. Fungi carried by beetles quickly spread through their galleries, killing trees. That is fortunate for the beetles because living pine trees produce copious amounts of resin in which the insects would be smothered. After beetle attacks, forests seem to change into devastated and forlorn seas of dead spars where only a short while before all was green. In fact, what has happened is only an acceleration of the natural process of replacing one tree species by another as forests reach maturity. Commonly, beneath upper canopies which have been killed, there is a lower canopy of hemlock or spruce which, given more light, gradually pushes through the dead tops. A green forest of different species is re-established until the next fire returns conditions once again favourable for pine. Many other kinds of insects also change the face of forests.

Diseases

Native forest diseases are generally less spectacular in their effects than insects. The heartwood of trees decays gradually until mature veterans have but a shell of solid wood. Except for conks (fungi often found on decaying trees), which are not always obvious, decayed trees are often hard to recognize until felling reveals a disappointing hollow centre. Decays are generally an "affliction" of old age. Root rots, on the other hand, affect both young and old trees. Openings occur in pole-sized as well as older stands as roots die, and trees, deprived of stability provided by healthy roots, die or topple over (Fig. 7). Such openings may be refilled by deciduous trees which, although adding aesthetic variety to conifer stands, reduce their commercial value. Needle-cast diseases may temporarily tinge hillsides as needles turn yellow before dropping off. Fortunately, needle diseases rarely are sufficiently persistent year after year to cause lasting damage.

Exotic diseases can be much more devastating. Blister rust is probably the most spectacular example to date in western North America. Brought into Vancouver in 1910 on white pine seedlings which had become infected in Europe, the disease quickly spread through coastal forests to the Interior. Within 25 years, red-topped trees became an all too familiar sight throughout the range of white pines. While pole-sized and older trees are rarely killed outright, seedlings seem to have little chance of survival

under natural conditions in the woods. Devastation of white pine stands in British Columbia is not yet comparable with the ravages of chestnut blight. In less than 40 years this disease virtually eliminated chestnut from the hardwood forests of eastern North America. It seems possible that the future of white pine as a commercial species is also in jeopardy unless man intervenes by propagating trees selected for their resistance to blister rust.

EPILOGUE

Although trite, it is true that British Columbia's forests are a vast heritage of wealth, aesthetic as well as economic, which contributes almost inestimably to the well-being of Canadians. During this province's early history, man's impact appeared miniscule on a seemingly limitless expanse of virgin forest. We now know that modern industrial man can cause a chain reaction of consequences even over such a vast area. Should we not remain alert to the fact that we do not know it all, conscious of the reality that the nature of British Columbia's forests is complex and often more fragile than the size of those giant trees bespeak ? When in doubt, should we not be cautious stewards rather than reckless consumers reaching for maximum immediate benefit, lulled by assurances that "you owe it to yourself?"

THE RICH ESTUARIES

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The last decade or so has witnessed a gradual and long overdue evolution of a sense of awareness of the ecosystems which surround us, an awareness of their complexity, of their roles, and in many instances, of their fragility. Gradually, too, our societies are slowly coming to realize that the progress and eventual fate of humanity rests to no small degree on an understanding of the ecosystems which we must, like all other species, depend on, and of which we are, or must become, an integral part. The human species cannot be regarded as an island unto itself, free from all of the restrictions which bound other species. Admittedly this concept is as yet far from universally acknowledged or accepted. When it comes to our willingness to accept natural ecosystems as vital units on the Earth's surface, and to accord them a measure of protection, our predjudices and bias' show up strongly. Stately forests, alpine meadows resplendent with masses of many-coloured blooms, coral reefs, sparkling fresh-water lakes - all these are readily appreciated for their aesthetic qualities if nothing else and, because of this, enlightenment as to their ecological roles and functions and legislation for their protection is more readily forthcoming. With my subject this morning, this happier state of affairs seldom exists.

Estuaries have so far not captured the general public's imagination, but in biologists' and naturalists' circles they are providing areas of increasing interest and concern. Lacking the immediate powerful visual impact of a primaeval forest or a beautiful lake, estuaries tend to have either been ignored or shunned as interesting landscape features by the public, or much more often, unfortunately, have been destroyed through "land reclamation" or development schemes of various kinds. This beauty of a natural estuary is far more subtle than that of a forest, lake, or alpine meadow, and full appreciation for it, as with opera, fine wines, or classical music, seldom comes without conscious effort on the part of the observer. Too often estuaries have been looked upon by man as unsightly blemishes on nature's beauty, places rife with unpleasant odours, places

the quicker filled in the better. As noted by Wesley Marx in "The Frail Ocean", "cities often encourage garbage collectors to dump their harvest on city-owned tidelands. This 'sanitary fill' fosters odours far more pungent than those emitted by virgin estuaries, odours that are then cited, paradoxically, as an additional reason to reclaim the estuaries and broaden the tax base. Fills also shrink the estuary's flushing capacity and concentrate the output of sewer outfalls." (Marx 1967)

What estuaries may lack in scenic splendour, however, they more than make up in overall ecological importance to the planet as a whole, for, unlike many other ecosystem types which may have marginal effects outside their own boundaries, estuaries affect surrounding ecosystems in profound ways.

What exactly are estuaries ? Broadly speaking, they are the regions where river and ocean meet, forming complex environments with elements of the terrestrial, fresh-water, and marine worlds. They may take many forms depending on the nature of the river or stream involved, and the topography of the adjacent continental shelf, but more often than not they are shallow, "clogged with marsh grass, bottomed with mud, split by a maze of channels and beset with mosquitoes and muggy odours". (Marx 1967) Many have been formed in post-glacial times, as the melting ice from the continental glaciers gradually raised the ocean levels. As the ocean levels rose, the incised lower channels of large rivers flooded, forming broad fan-shaped estuaries. Such areas today are hardly uniform but are instead complex mosaics of marshland, soft, oozing mudflats, submerged at high tide but exposed at low, and permanently submerged areas of shallow water. Such places hardly sound promising but in reality are biologically, incredibly, productive, as productive as the richest tropical ecosystems. Odum (1961) estimates estuaries as being about 20 times as productive as the open ocean and two to ten times as productive as most of our agricultural areas. In nature, only coral reefs and tropical lowland rainforests are thought to equal the productivity of estuaries. The causes of such great productivity are many fold, but the following are perhaps of greatest importance.

Estuaries with their tidal marshes, receive an almost constant flow of nutrients from the river and from the sea, but in addition to receiving these copious supplies of nutrients, estuaries also possess the means

of trapping them. In part, the shallow waters themselves act as nutrient traps in which particles settle in the bottom sediments. More importantly, most estuaries have abundant clay sediments composed mostly of kaolinite and montmorillonite. The clay particles which make up these sediments act as micelles much as they do in terrestrial soils. Micelles are complex negatively charged particles capable of absorbing large quantities of a variety of positively charged ions. These nutrient ions, including calcium, magnesium, and potassium, are held on the surfaces of the clay particles in the clay sediments as "nutrient buffers". Such nutrients are released from the clay sediments into the waters as nutrients already in the water are removed by plankton (Wagner 1974).

In addition, the constant mixing of fresh and salt water through river flow, tidal action, and storm activity ensures a constant scouring, circulation, thus recycling the bottom sediments. This is instead of the trapping of large quantities of nutrients in sediments inaccessible to living organisms for long periods of time. This constant physical recycling of nutrients plays a major role in increasing the fertility of estuaries.

Green plants form the living base of most ecosystems and, in their role as primary producers, are vital to the existence of all other organisms higher than themselves on the food chains. Green plants need both heat and light to flourish and both are abundant in estuaries because of the shallow water. In summer, the shallow waters of the marsh and mud-flat areas heat up quickly and productivity soars. Winter of course brings low water temperatures, outlining the need for estuarine plants and animals to be able to adapt to temperature extremes.

These factors all combine to result in great biological productivity, higher than either the adjacent sea or the land, and capable of producing up to ten times the biomass per year as the same area of productive wheat field. (Wagner 1974)

Although estuaries vary greatly from place to place, in north temperate areas they are frequently roughly divided into salt or tidal marshes, mud flats, and estuarine waters, the last permanently submerged. The composition of each varies greatly from place to place. Around Vancouver, for example, the salt marshes are usually dominated by species of rushes (Scirpus)

which frequently account for 85% or more of the marsh plants, with the remainder made up of plants such as the common cat-tail *(Typha latifolia)* and sedges *(Carex* spp*)* (Wade, 1972).

In tropical estuaries by contrast, a more spectacular note is added by the presence of dense groves of mangrove trees in the marshes. With their rather grotesque forms and their multitudinous aerial roots, they add a decidedly exotic touch to an otherwise rather sombre ecosystem. *Nipa* palms and *Hibiscus tiliaceous* also brighten tropical estuaries.

Despite the high productivity of estuaries, it has been frequently noted that the amount of plant biomass actually eaten by other organisms each year is relatively low, perhaps less than 5%. Most of the marsh plant biomass survives until crushed and fragmented and winter storms, after which it is "broken down by microorganisms into fine organic particles containing much protein, carbohydrates, and vitamins. These materials are distributed by tides but retained and cycled by various organisms in the ecosystem" (Wagner 1974). Such particles, with their associated bacteria, algae, and protozoans, make up much of the organic detritus of the estuaries and as such provide a beginning link in several food chains as a valuable food source for filter feeders such as clams, mussels, amphipods and other crustaceans.

One of the features of estuaries which is of enormous ecological significance is their ability to produce far more food than is consumed by permanent estuary residents. This excess, which is considerable, is utilized by migratory birds, fish and other inhabitants, for whom the existence of the estuaries is absolutely vital to their survival. Perhaps the most obvious of these "temporary" residents are the migratory water birds, the ducks, geese, and swans, which use estuaries extensively both during migration and as winter feeding and resting areas. The use of the Sturgeon Banks of the Fraser River estuary by thousands of Lesser Snow Geese each year is a good case in point. Many other birds of course use the estuaries including shorebirds, some songbirds, rails, bitterns, herons, and farther south ibis, spoonbills, and egrets. It is now generally accepted that estuaries play a vital role in the maintenance of healthy populations and many migratory aquatic bird species.

Less obvious among the "temporary" residents, but in the long run perhaps even more important, are the various species of oceanic fish which use the estuaries as either spawning grounds, nurseries, or temporary feeding areas. In coastal British Columbia for example, larval herring feed extensively in estuaries before moving elsewhere, while the young of pink, chum, and spring salmon spend from several weeks to several months feeding in estuaries before moving out to sea (Burgess 1970). In addition to this use as valuable feeding areas, the role of estuaries as brackish-water, transition areas for fish moving from fresh water to salt water or the reverse may be very important. Estuaries may also serve as areas in which anadromous fish undergo physiological adjustments which enable them to cope with the osmotic problems faced by organisms moving from sea to river. Such a "transition period" in such a "transition area" may well be essential. With salmon in the Pacific fitting this category, and Atlantic salmon, striped bass, shad and alewife on Atlantic shores, estuaries begin to assume great economic importance. On the Atlantic coast of North America more than 60 species of commercial and game fish (among them tarpon, snook, menhaden, red drum and striped mullet (Wagner 1974)) spend significant portions of their early lives in estuaries. The enormous economic value of many of these species is further confirmation of the overwhelming importance of estuaries. These few examples indicate that, in their value to animal populations, estuaries have exceedingly far-reaching effects, beyond their own boundaries and more profound than either their size or superficial appearance suggests.

Importance as well, of course, are the permanent animal residents. The Sturgeon Banks in British Columbia supports large populations of starry flounders *(Platichthys stellatus)*, black-tailed shrimp *(Crage nigricauda)*, burrowing shrimp *(Callianassa californiensis)* and various clams *(Tellina, Macoma, Schizothoerus, Mya)* (Wade 1972). In other estuaries on the Atlantic Coast various species of oyster, shrimp, scallop, and clam are also very abundant and of enormous commercial importance. Most of the shrimp fishery of the eastern American coast, apparently the most valuable marine animal crop in the U.S., is totally dependent on estuaries (Marx 1967). The examples could go on and on, but would only strengthen the point of the biological importance of the estuary.

I would like to finish by a short consideration of a rather

different characteristic of estuaries, which is not raised nearly as often as the points I have already made. This consideration is that of species diversity. Despite the enormous productivity of estuaries, or in other words the enormous biomass produced, the species diversity in estuaries is low. There exists in ecosystems a direct correlation between species diversity and environmental stability. Ecosystems occurring in areas that are environmentally highly stable, such as the deep seas or many tropical areas, are very diverse in species. Lowland tropical rainforests and coral reefs for example are unparalleled in terms of the numbers of species composing them. This great diversity of species, the result of long-term environmental stability, itself promotes greater stability within the ecosystem. Ecosystems rich in species are stable ecosystems and are far less vulnerable than ecosystems poor in species. The "stability in diversity" concept has become vital in the annals of ecology. It is now generally accepted that the most diverse ecosystems are the ones most likely to survive over the long run. A human analogy can be found in the vulnerability of the agricultural "monoculture" versus the built-in safeguards of mixed agriculture. In this regard the estuaries do not come off well. The estuarine environment is anything but stable, rather it is just the reverse. Here forces combine to produce one of the least stable physical environments on Earth. Seasonal changes in temperature, salinity, and fresh-water flow are great, and when combined with diurnal tidal and temperature differences as well as sporadic storm activity, produce an environment inhospitable to all but a few species. The few species which have successfully adapted to estuarine life have become sucessful indeed, usually existing in great numbers and forming the basis for the estuary's great productivity. Their success story however does not negate their vulnerability or the vulnerability of the whole ecosystem to which they belong. Potatoes too were thought a highly productive crop prior to the Irish potato famine !

The potential vulnerability of estuaries should be kept constantly in mind, as should their great biological value, when decisions on land use are made. The great value of estuaries, both as ecosystems in their own right, and for the roles they play in the life histories of many species of other ecosystems, should be abundantly clear. Their potential vulnerability due to their lack of great species diversity must also be appreciated. Once estuaries are destroyed they are gone for the forseeable future - there is

little evidence that they can regenerate with the comparative ease of a forest. Preservation of the all too few remaining estuaries should be encouraged - demanded - at all costs. Far too many of these priceless ecosystems have already been destroyed through deliberate planning or short-sighted thoughtlessness. We must act to stop the destruction of these that are left, or reap the contempt of future generations.

* * *

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SEA-BIRDS BREEDING ON THE CANADIAN WEST COAST

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Despite the fact that more than two-thirds of our planet is covered by water, only 3% of the 8,600 species of birds known today are true sea-birds. The term sea-bird itself is vague, but most ornithologists divide the complex into four major groups, the penguins (Sphenisciformes), the albatrosses, storm-petrels and diving petrels (Procellariiformes), the gannets, boobies, pelicans and cormorants (Pelecaniformes) and the largest order, the jaegers, gulls and auks (Charadriiformes). Despite their small number of species, sea-birds compose a large part of the world's bird population. One of them, the Northern Fulmar *(Fulmarus glacialis)* was once thought to be the most numerous bird species in the world. That distinction now goes to the Wilson's Petrel *(Oceanites oceanicus)* (8).

Sea-birds occupy an essentially marine environment which they share with other organisms, plant and animal. All have become adapted to particular niches in this environment through natural selection and evolution. Just what are the adaptations that enable sea-birds to survive in a constantly wet environment devoid of fresh water ? For swimming and diving, their structural adaptations include webbed feet, compressed tarsi, special knee joints for muscle attachment, legs at the rear of the body, spindle-shaped body, "heavy" bones, and overlapping rib projections (for deep divers).

Other adaptations, too numerous to mention here, are known in each species' life history, but all sea-birds have evolved two specialized glands that are peculiar to the group. One, the uropygial gland, located on the bird's rump, produces oil when squeezed by the bill, which, during preening, is spread over the feathers. This protective coating ensures that the plumage remains in good condition and waterproof. Recent studies have also shown that if swallowed, the oil, which contains significant concentrations of vitamin D, may be a valuable supplement to the diet.

While it is known that too much salt in an animal's diet can result in death, and that sailors formerly believed that sea-birds visited large coastal lakes for fresh water, sea-birds do drink sea water. They excrete excess salt, not through their kidneys but via a salt gland usually located in the head [16]. The concentrated salt solution is secreted in drops from the tip of the bill, or, as in the Procellariiformes, ejected from tubes atop the bill.

Biologists generally agree that the availability of food is the major limiting factor in the distribution and numbers of sea-birds. Their principal food resources, plankton and fishes, are not evenly distributed throughout the ocean but are more abundant in areas where upwelling and turbulence occurs and where nutrients of nitrogenous and phosphorous compounds are concentrated by currents to form pools of planktonic life, the pasturage of the sea.

Sea-birds have met the challenge of this uneven distribution by evolving as strong flyers with almost limitless endurance.

Sea-birds, like their food resources, are distributed unevenly around the oceans of the world. The largest concentrations are found in the Pacific, where nearly half of the known species may be seen. Colder ocean currents have a far higher density of plankton than warmer areas. This is probably why numbers of sea-birds found in the Pribilof Islands, in the Bering Sea, equal those found off the coast of Peru, where the cold waters of the Humboldt Current produce a food cycle of the sea in its most dynamic form.

In British Columbia the distribution of sea-birds may be divided into three rather loosely-defined zones --inshore, offshore and pelagic While there may be seasonal overlap between zones, this paper is primarily concerned with those species which occupy the offshore zone and which utilize islands for breeding.

BRITISH COLUMBIA SEA BIRDS

Thirteen species of sea-birds breed in British Columbia. They include two storm-petrels, three cormorants, a gull and seven auks [7] [20]

One auk, the Marbled Murrelet *(Brachyramphus marmoratum)* remains a mystery. While the bird is common along our coast, its nest is yet to be discovered here; but fugitive young from the nest have been found, one on the shore of Lost Lagoon in Stanley Park, Vancouver [4]. In 1974, however, a tree surgeon working in the Santa Cruz Mountains, California, discovered the nest of a Marbled Murrelet on a moss-covered limb, high above the forest floor, and some distance from the sea, the first positive breeding record for North America [19].

Small numbers of Horned Puffins *(Fratercula coriculata)* undoubtedly nest in British Columbia, possibly on Solander, Triangle and St. James Islands, but this still needs to be confirmed. Northern Fulmars have been seen "inspecting" sea-cliffs off northwestern Vancouver Island and in time may nest there. Positive evidence of breeding for both these species would bring the number of species breeding in the province to 15.

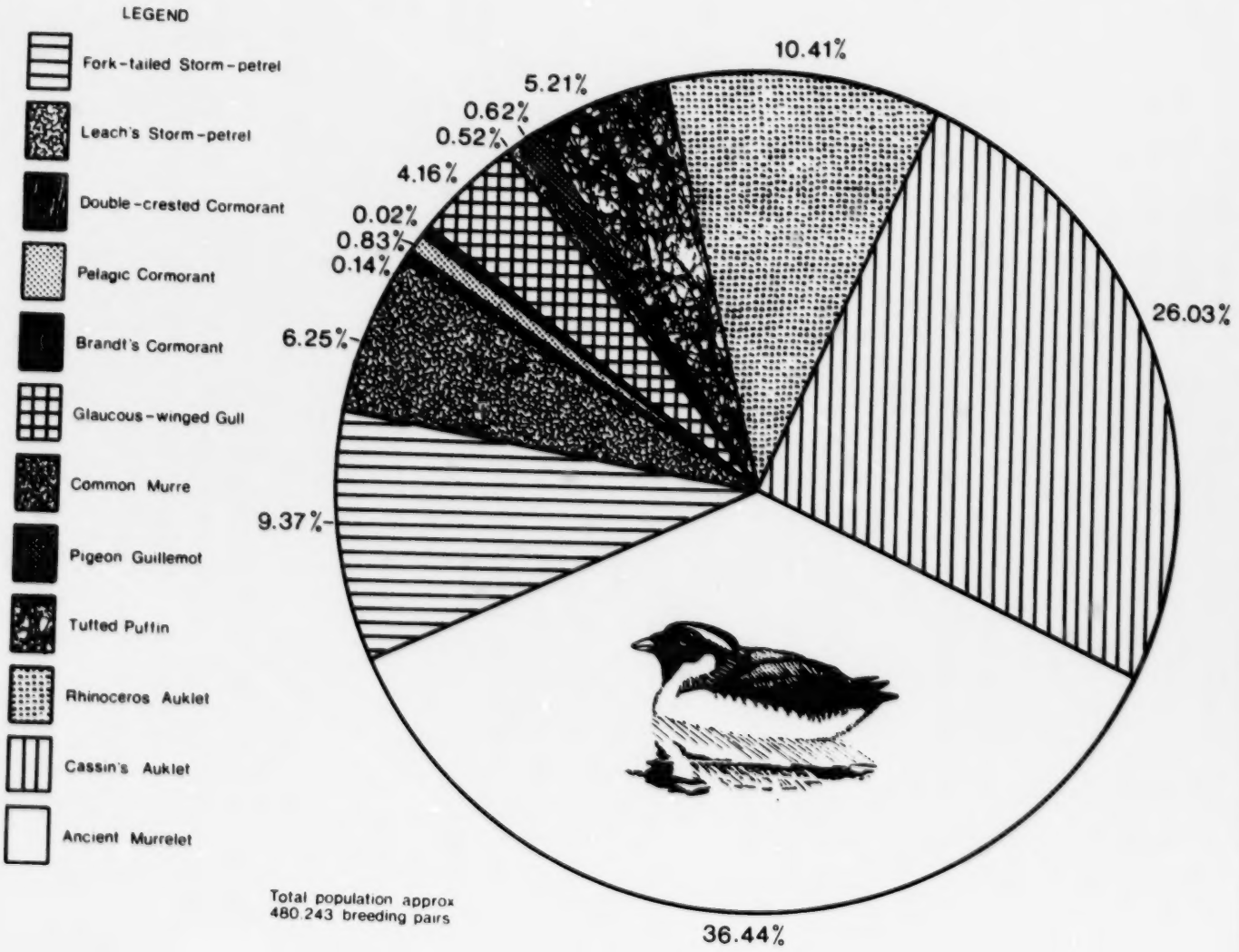
Approximately 480,000 pairs of sea-birds breed along British Columbia's 15,000 miles of shoreline. Another million or so non-breeding birds bring the total population to about two million, a surprisingly small total when compared with the Aleutian Islands, a few hundred miles to the northwest, where an estimated 2.8 million sea-birds breed [18], or with individual islands along Alaska's north coast each of which may support nearly a million breeding birds [1].

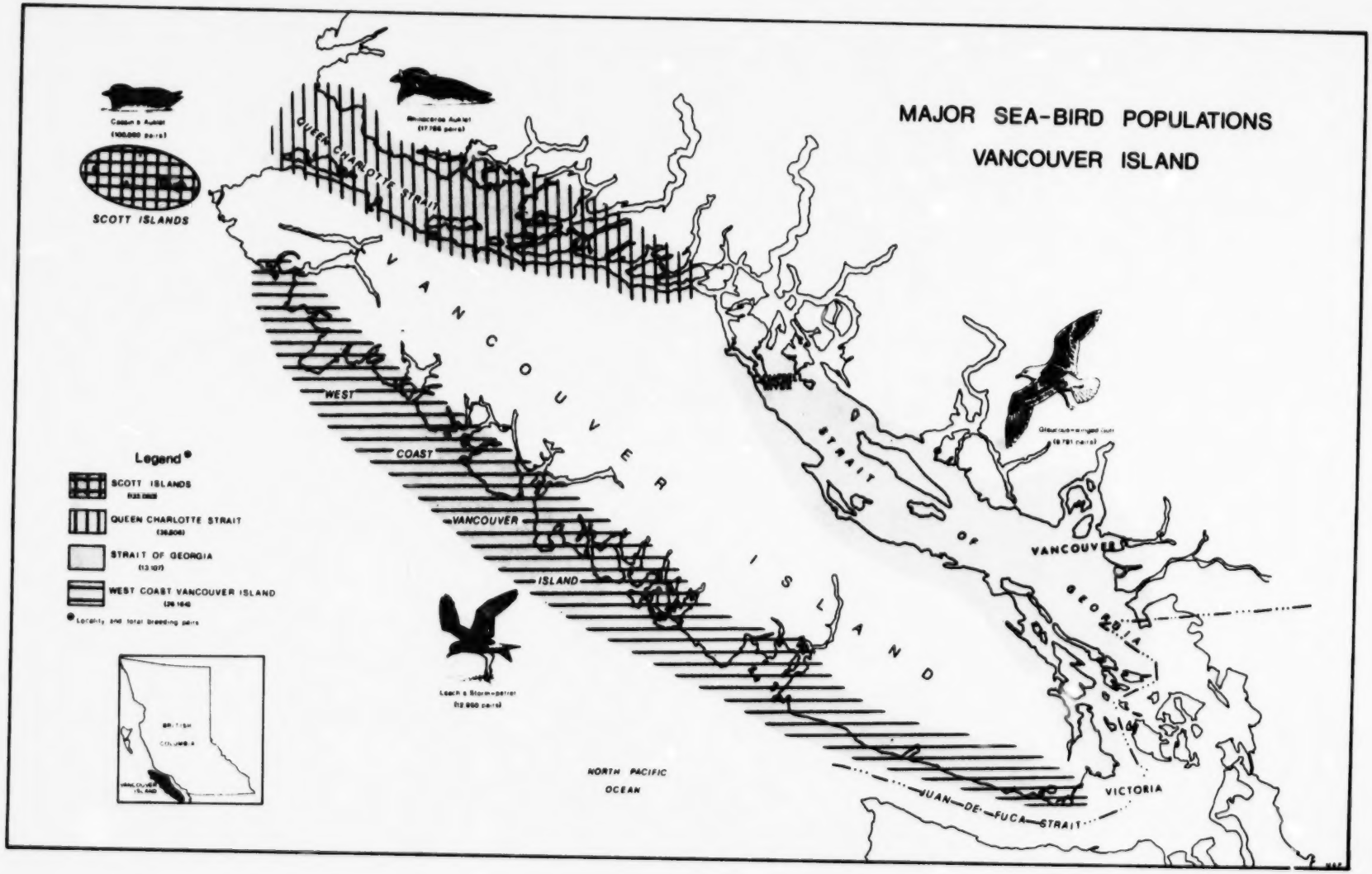
The paradox of British Columbia's sea-bird population is that those species which are the most conspicuous, being active in daylight, therefore appear to be the most numerous - the surface-nesting gulls, cormorants and murres - are actually a minor part of the total population. In fact 95% of the sea-birds breeding in British Columbia, nest hidden in burrows or crevices and many of them are more active at night than in the daylight. Because they are subjected to fewer environmental extremes (moisture, light and temperature) they may be more successful, hence more numerous, than those species whose nests are exposed to the elements. The largest sea-bird populations in the province are adjacent to plankton-rich areas off northwestern Vancouver Island and the Queen Charlotte Islands.

Storm-petrels

These are the smallest sea-birds in the province, slightly

SEA-BIRDS BREEDING IN BRITISH COLUMBIA




MAJOR SEA-BIRD POPULATIONS
VANCOUVER ISLAND
SCOTT ISLANDS
QUEEN CHARLOTTE STRAIT
VANCOUVER ISLAND
WEST COAST
VANCOUVER ISLAND
STRAIT OF GEORGIA
VANCOUVER
VICTORIA
JUAN DE FUCA STRAIT
NORTH PACIFIC OCEAN
Legend
SCOTT ISLANDS
QUEEN CHARLOTTE STRAIT
STRAIT OF GEORGIA
WEST COAST VANCOUVER ISLAND

larger than a Barn Swallow and weighing but an ounce or two. Seen at sea they have a bat-like flight and appear to walk upon the surface of the water in their search for food. The Fork-tailed Storm-petrel *(Oceanodroma furcata)* and Leach's Storm-petrel *(O. leucorhoa)* breed on isolated islands along the outer coast. While Fork-tails may occasionally nest solitarily the storm-petrels are essentially colonial nesters and colonies are often dense: one, occupying a patch of vegetation 300' by 150', contained an estimated 5,000 pairs [2].

Fork-tailed Storm Petrel

The nesting sites are short burrows, excavated in soft soils among herbaceous growth, or in open spruce forests. Slope, necessary for flight from the colony for some species, does not appear critical for storm-petrels. The reproductive period lasts nearly four months; they may arrive on the breeding grounds in April and not leave until September. A single, white egg is incubated for about seven weeks by both parents, who

exchange duties every three days or so. (By comparison the incubation period for an American Robin *(Turdus migratorius)* is less than two weeks). Another 10 weeks is required before the fat chick scrambles from its burrow to the sea.

While at sea, searching for plankton, adult storm-petrels are silent, but when relieving nest mates, in darkness, they are extremely noisy. A highlight of my life was sitting in the dead of night listening to storm-petrels exchange "love notes" as each returning bird located the two-inch entrance to its burrow among thousands of others hidden by grasses. Because of the nature of the terrain in which they breed, and their nocturnal habits, true assessments of storm-petrel populations are difficult to make. Together, both species account for about 15% of the total sea-bird population of British Columbia, about 75,000 pairs.

Cormorants

Cormorants are among our largest sea-birds which, because of their overall brown-black plumage, are often called "sea-crows". They are expert divers, diving from the surface with a distinct forward leap, propelled by their large webbed feet. They are entirely fish eaters. Three species occur in British Columbia.

Double-crested Cormorants and Glaucous-winged Gulls nesting on Ballingall Islets.

On the British Columbia coast, the Double-crested Cormorant *(Phalacrocorax auritis)* is restricted to the Gulf Islands in the Strait

of Georgia, although it is found throughout the interior of much of North America. This species moved into British Columbia in 1927, probably from saturated colonies along the northern Washington coast [13]. By 1960 at least 150 pairs nested in the province [7] and by 1975 the population had swelled to 671 pairs. Colonies are compact, their size depending on the number of bulky stick nests that can be jammed into a suitable area. Cliff shoulders, flat, gently-sloping rock faces, and trees, provide suitable habitat. Some nests survive winter storms and, with annual use, in time reach heights of up to four feet. Nest-building is mostly carried out by the male but both sexes share incubation. The four or five chalky-blue eggs are incubated on the large, warm, webbed-feet of the adult birds and hatch in about a month. The black chicks are born naked and blind and resemble reptiles. This is a critical period in the life cycle because, if disturbed, chicks can die from too much heat or chilling from unseasonable rain. Nestlings are fed regurgitated fish and when seven weeks old become independent and leave the colony.

The Pelagic Cormorant *(P. pelagicus)* is our smallest but most numerous and widely distributed cormorant and ranges along the entire coast. Although precipitous cliff-ledges are the characteristic nest substrate, lightstations, drift-logs piled up on islets, and gently-sloping rock promonitories of sufficient heights are also used. Nests are sparse to elaborate collections of grasses, seaweeds, and marine debris, which often become blanketed with guano as the season progresses. By various displays and gestures the male attracts a prospective mate to "his" nest where mating takes place. The clutch of four to six eggs is incubated by both parents who, when incubating, face the cliff (for obvious reasons) with their long tails pointing seaward. The reproductive period lasts about 11 weeks. Some nesting colonies contain several hundred pairs but isolated nests are not uncommon.

The third cormorant, the only one restricted to the Pacific Coast, is Brandt's Cormorant *(P. penicillatus)*, the newest arrival in British Columbia and the least numerous but perhaps, paradoxically, the most familiar. It is the species that ferry travellers, between Vancouver and Victoria, see in immense feeding flocks in Active Pass each winter. Less than 100 pairs breed on tiny, rocky islets, off the central west coast of Vancouver Island, where they were discovered in 1965 [9] [20].

Banding programmes in the United States have revealed that these birds originated from colonies off the California coast.

Brandt's Cormorant

Brandt's Cormorants nest later than the other two species, often not completing their nest of assorted marine debris until late June. Most clutches are laid in July and by late August and early September young of all sizes gather in "family" flocks on the islets before leaving for the sea. Banding returns of young in British Columbia indicate a southward movement from the natal colony. However, each July and August there is a heavy northward movement of Brandt's Cormorants from California along the outer coast of Vancouver Island.

Together, the three species of cormorants comprise about 1% (4,743 pairs) of the total population of breeding sea-birds in British Columbia.

Gulls

Gulls are the most familiar of all sea-birds. Only the Glaucous-winged Gull *(Larus glaucescens)* breeds along the British Columbia coast although the smaller Mew Gull *(L. canus)* nests on fresh-water lakes near the coast. About 20,000 pairs of Glaucous-winged Gulls breed in the province, half of them around the Strait of Georgia near centres of human settlement. There, the gull population is increasing each year, probably due to a readily available source of food in the form of garbage, and to new nesting areas (e.g. breakwaters, jetties) being created, both the result of human activities. Crow-control programmes, discouraging the collection of gull eggs by Indians, the protected status of the gulls and the protective activities of wardens at some sea-bird colonies, have also contributed to this increase. Saturated colonies may be forcing gulls to breed in marginal habitat (e.g. shore situations, gravel roof tops) (5).

Adult gulls at most south-coast colonies are occupying territory in February and March and by mid-May the grassy nest contains two or three eggs. The first young appear by July and by mid-August those that survive the hectic and competative life in the colony leave to forage on their own.

Teacher's and students learn about the sea-bird colonies while assisting a bird branding team from the British Columbia Provincial Museum.

Each year, about the third week in July, several thousand downy chicks are banded by staff of the British Columbia Provincial Museum. These tell-tale aluminum bracelets are helping to provide many answers to questions about the fascinating life-history of this common bird. For example, as a result of banding we know that the Glaucous-winged Gull can live at least 26 years [6]; the younger the gull, the further it wanders after the nesting season; recently fledged young may travel as far as southern California (one followed a ship to Midway Island in the South Pacific); that they attain sexual maturity at four years by which time 80 to 90% of the original population have died, most from starvation. Banding has also shown that adults may travel as far as 50 miles, round trip, to obtain food for their young [7]. In the future, banding may indicate what effects over-population may have on their mortality rate and distribution. Devoted amateur ornithologists who spend countless hours looking through a telescope at gull legs for bands and then recording the numbers, have gathered this data.

Auks (Alcids)

These diving birds comprise nearly 80% of all the sea-birds breeding in British Columbia. Ecologically, auks are the northern counterparts of penguins and diving petrels found in the southern hemisphere. The life histories of the six species found in the province are as varied as the birds themselves and much still remains unknown.

About 2500 Common Murres *(Uria aalge)* breed in British Columbia, most in the Scott Islands. A small colony has recently become established off central Vancouver Island and others may be found in time along the outer Queen Charlotte Islands. These colonial nesters lay a single, pear-shaped egg in mid-June, usually on a bare, exposed rock ledge high above the sea. Evidence that murres may once have had two-egg clutches is found in their incubation patch which changes from two oval shapes to a single oval shape, at a critical time in incubation [21]. Most naturalists know that the pyriform shape of a murre's egg is an adaptation to prevent it from rolling off narrow ledges as a result of high winds or nesting activities. According to Leslie Tuck [21] this is only part of the story. He says "fewer eggs fall toward the end of the incubation period that at its beginning . . . important changes are taking place within the egg which

aid in its stability. As incubation proceeds, the radius of the curve described by the egg when disturbed is diminished".

Common Murre

The chicks are raised on a diet of fish which the parents catch by "flying" under the water. Some dives are as deep as 40 fathoms but most fishing takes place in relatively shallow, turbulent water. In late July chicks fledge, simply dropping off the nest ledge to the water below, and join their parents who may take them as far as 20 miles to sea. Large rafts of murres winter off the southern British Columbia coast.

The black and white Pigeon Guillemot *(Cepphus columba)* is an ubiquitous species, most often seen during the breeding season on "loafing" rocks where they establish a territory by body postures and shrill whistles. They mate there before travelling to some rock crevice, pile of beach logs, wharf, or beached marine debris, to lay their two eggs. Both parents incubate and rarely, if undisturbed, do they leave their eggs unattended

for more than 10 minutes. Two months is required from egg-laying to fledging. During its development each chick receives about 10 fish a day, mainly blennies and sculpins [7]. After leaving the nest the chicks are on their own and probably never knowingly see their parents again.

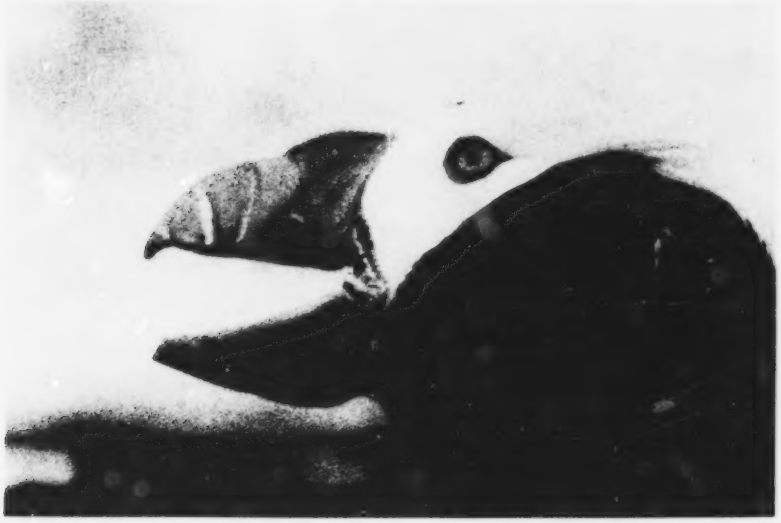
Pigeon Guillemot

Because of their solitary nesting habits, estimates of Pigeon Guillemot populations are only educated guesses but probably 3,000 pairs breed in the province.

Everybody knows a puffin but few can tell us much about the bird. This is especially true of the Tufted Puffin *(Lunda cirrhata)*. About 25,000 pairs of these colourful birds breed in British Columbia, most in dense colonies on the Scott Islands. Puffins return to nesting colonies in mid-May after spending the winter somewhere at sea. Mating occurs on the water after which a long burrow is excavated using the large bill and sharply-nailed toes of the feet. A single, white egg is laid in a nest chamber sprinkled with dry grasses. Both parents incubate. Little else is known about their life history but it is only a matter of time before some biologist or graduate student falls in love with this comical "sea parrot" and produces a monograph on them.

Puffins are fish eaters and dive for their food from the surface of the sea. Backward-pointing serrations along the bill and tongue

no doubt aid in holding slippery fish. But how the bird manages to catch a seventh fish, while already holding six jammed in its bill, is a riddle biologists still ponder. It is one secret I hope the puffin keeps !

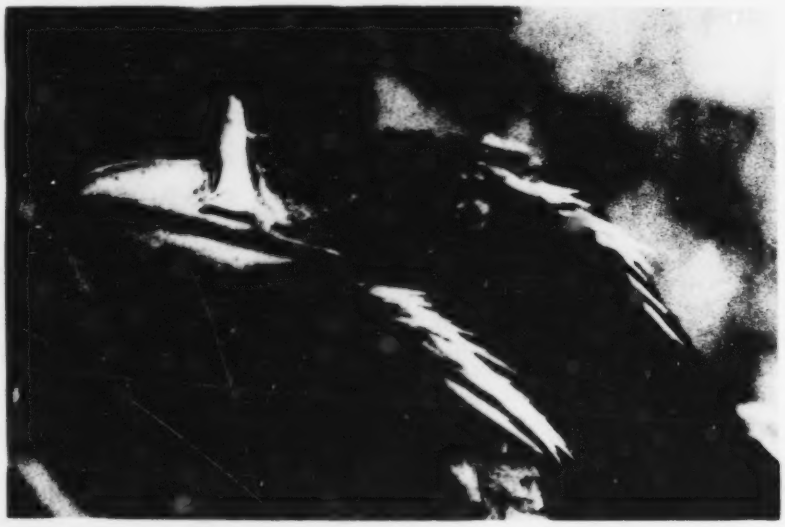


Tufted Puffin

Our most bizarre sea-bird, the Rhinocerous Auklet *(Cerorhinca monocerata)* gets its name from a blunt projection at the base of its upper mandible. There are twice as many Rhinos as puffins in the province, and their numbers appear to be increasing. Colonies of hundreds of them, probably originating from over-populated colonies in Washington, have recently become established along the west coast of Vancouver Island. Rhinocerous Auklets are nocturnal at the nesting colonies although adults can be seen in the vicinity during the day.

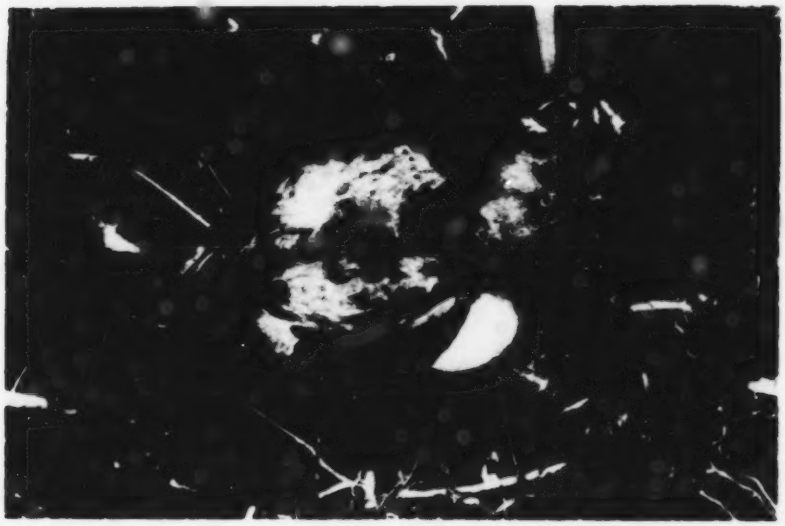
When Rhinocerous Auklets first arrive in May their evening flights are haphazard and noisy but as the season progresses the sound of beating wings and the rustle of birds searching for burrows are the only evidence that they are present. Wooded islands are preferred habitat; there, a lengthy burrow is constructed, sometimes 20 feet long, which intertwines among tree roots and boulders. A single, white egg is laid in May

and by late July the first young may appear on the sea. Rhinoceros Auklets are also fish eaters, their favourite being sandlance, and they may travel distances of up to 120 miles, round trip, to the feeding areas [10].



Rhinocerous Auklet

The remaining two nocturnal alcids, Cassin's Auklet *(Ptychoramphus aleutica)* and the Ancient Murrelet *(Synthliboramphus antiquum)*, account for over 60% of breeding sea-birds in British Columbia. Fortunately, recent field studies have filled-in many of the details on their complex life histories [12] [17]. Cassin's Auklet is widely distributed along the Pacific coast ranging from the Aleutian Islands to central California. Our largest colony, on Triangle Island, is estimated at 100,000 pairs. In the southern part of their range at least, Cassin's Auklets are resident. There they visit nesting islands throughout the year and may even form a pair-bond that lasts several years. While they may nest in a variety of crevices Cassin's are primarily burrow nesters and are usually heard arriving at the colonies shortly after dark. Eight weeks are required from the time the egg is laid until the young auklet is fledged. Mates exchange incubation duties every 24 hours. When foraging at sea, between periods at the nest, they store shrimp-like euphausids and amphipods in a throat pouch to carry back to the nestlings.



Cassin's Auklet

The Ancient Murrelet is our most numerous sea-bird. All of the 175,000 pairs which breed along the British Columbia coast, nest on forested islands around the Queen Charlotte's, the largest colony on Langara Island off their northwest tip. These colonies represent the southern limit of their breeding range which extends northward to Alaska and west across the Bering Sea. Unlike other burrow-nesting alcids, the eggs of Ancient Murrelets are blotched on a deep-buff base, which seems to suggest that at one time in their evolutionary history Ancient Murrelets laid their eggs out in the open, perhaps like Marbled Murrelets.

Both adults incubate the two eggs, for about 35 days, with an incubation shift lasting 72 hours. The downy chicks are fed various kinds of zooplankton for the first two days after hatching. They then scramble from the burrows, under the cover of darkness, to join their parents on the sea. Their feet, at this time, are nearly adult in size, which enables the chicks to accompany their parents to offshore feeding areas. This fledging exodus may occur any time from late May to early July.

THREATS TO SEA-BIRDS

Sea-birds vary greatly in their biology and response to environmental changes, whether these occur at the nesting colonies or far at sea. Before man appeared, disease, parasites, predators, inclement weather and climatic changes affected their numbers and distribution. But our planet is becoming an increasingly man-dominated environment and we are doing things today that nature has carefully avoided for eons. Marine pollution, for example, has reached global extent in only a few decades. Thus sea-birds are faced with a somewhat unnatural and overwhelming force that will affect their livelihood in the years to come.

Man affects sea-birds both directly and indirectly. Hunting, netting, trapping, shooting and egging involves direct interference but fortunately these have never been a problem in British Columbia. In eastern Canada, Russia, Greenland and Europe, however, some sea-bird colonies have been reduced to such low levels by human harvesting that they will never recover. For example, in the last century, murre eggs were harvested from colonies along the Gulf of St. Lawrence with as many as 750,000 eggs being taken annually. By the end of the century this uncontrolled practice had led to the extermination of some colonies. Today, even under the protective laws which have now been in existence for many years, the surviving murre colonies have not returned to their former size. Had they reached a point "beyond which recovery of such highly colonial birds was impossible " ? (21) Few countries in the world today harvest sea-birds although recent Russian research has shown that if murres are harvested in a scientifically controlled manner little harm is done to the colony.

Hunting for pleasure, rather than food, has never had a great impact on sea-birds in British Columbia. In fact, I doubt if it has any significant impact anywhere in the world today. The sum total of man's direct interference on sea-birds, therefore, is probably small. The indirect effects of his activities, however, are great and increasing.

Sea-birds nest on isolated islands to avoid terrestrial predators, therefore, the accidental or intentional introduction of alien animals could certainly alter, and might completely destroy, the delicate interrelationships that are essential to a viable nesting colony. Predators (such as

Indians harvesting sea-bird eggs on Mittlenatch Island

snakes, mice, rats mink, otters and cats) can attack and kill adults or eat eggs or young. Rabbits and hares can compete for living spaces, and domesti livestock (e.g. goats and sheep) can significantly damage vegetation and soil Some of the larger land predators, like mink and river otter, can easily swi to offshore islands where, once established, they can completely destroy vul nerable colonies or gradually reduce the population to the point where recovery is impossible. Only anecdotal accounts exist in British Columbia on the effects of these predators. Recently it was learned that storm-petrels may form an important part of the summer diet of river otters *(Lutra canadensis)* and that mink *(Mustela vison)* may kill substantial numbers of sea-birds, stock-pile them at denning sites, and never utilize them.

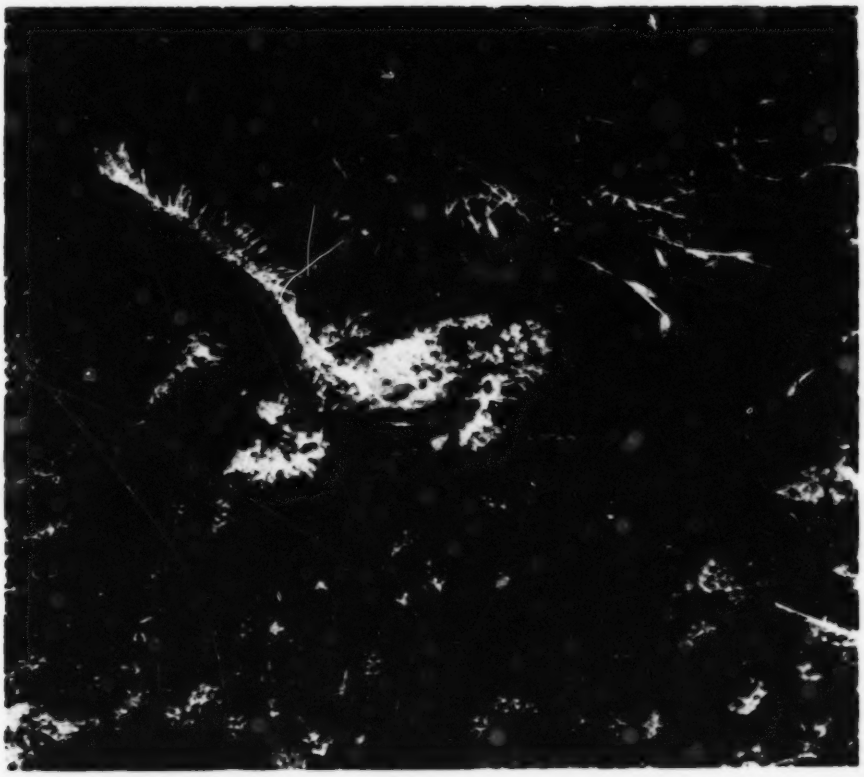
To date, such introductions have not been a problem in the province, more by good fortune than by design. For example, the Black Rat *(Rattus alexandrius)* has become successfully established on Langara Island, the largest Ancient Murrelet colony in British Columbia. Although they prey on murrelets and their eggs [3], their total effect as predators appears negligible [17]. The situation could have been much different if the mink, intentionally introduced onto the Queen Charlotte Islands in 1972 by fishermen had survived. The potential for unintentional introductions, however, grows each year. Tourists, boating enthusiasts, fishermen and loggers should be informed of the inherent ecological effects of visiting off-shore islands. Biologists as well should develop a monitoring programme which would expose potential conflicts between introductions of land predators and their effect on sea-bird populations.

Another threat to sea-birds results from altering their nesting sites by man-associated activities, such as the construction of navigational and recreational buildings (e.g. lightstations and cottages) and logging practices. In most cases direct loss of habitat results but sometimes the indirect efforts, such as erosion, disturbance, and animal introductions, can be just as serious. Pets, especially dogs where they are allowed freedom to roam among nesting colonies, have been known to kill hundreds of gulls and auklets. In some cases such disturbance has caused colonies to relocate.

Some islands that support nesting sea-birds are privately owned and, therefore, beyond legal protection. However, the chance that others may be purchased and sub-divided for vacation homes in future is becoming remote, especially since most major colonies are now protected as provincial ecological reserves.

Guidelines for logging activities on large off-shore islands are now being prepared by the British Columbia Fish and Wildlife Branch. Hopefully, these will include the present as well as the future requirements of burrow-nesting sea-birds. Because birds are not utilizing a particular forested island now doesn't mean they won't in the future, therefore, any island of less than 100 hectares should be protected completely from logging and other human developments [14].

Man, in his constant search for additional food resources, may



A young gull, a victim of the beds of cactus that occur on some sea-bird colonies.

unknowingly be affecting the livelihood of many species of sea-birds. Modern fishing fleets may be overharvesting some fish stocks. In fact some species of fish may have already gone the way of the great whales. Unfortunately basic research on the biology of fish populations is lacking as is the impact that sea-birds may have on fishes. For example, sea-birds depend on large, predatory fish to chase smaller schooling fishes such as herring and sandlance, to the surface where they can be obtained by the birds. Overfishing of fish such as tuna and salmon then could initiate an ecological chain reaction in which sea-birds were indirectly affected.

There is also the direct mortality to sea-birds through commercial fishing. Hundreds of thousands of sea-birds are killed each year, most by drowning in drift, gill-net and longline operations. It has been estimat that the Pacific salmon fishery, comprising United States, Canada, the Sovie Union, Japan, Australia, New Zealand and Chile, may kill one in every hundre

birds from a summer standing stock population [11].

In some areas the "total annual mortality has likely exceeded recruitment for a decade now" [11]. As many as 75,000 birds, including pelagics such as shearwaters, may be killed every day in the Bering Sea by Japanese and Soviet commercial gill-netters. The toll then is staggering and the problem is serious enough that biologists must meet, on an international level, to prepare management guidelines. Unfortunately, at present only the Danes make use of the killed birds. The other countries have no interest in them for human consumption. On the other hand, offal from fishing fleets provide a readily available food supply for birds like gulls and fulmars which, no doubt, has contributed to the sharp increase in their numbers. A backlash may result, however, when by sheer numbers, these scavenging species become a threat to other sea-birds, either by preying on them, harassing them, or ultimately by occupying their nesting areas.

Well-meaning, but uninformed tourists, vacationers, naturalists and biologists pose another indirect threat to sea-birds through disturbance, fires and garbage. While less significant than other threats, the local effect of such disturbance can be great. For example, on colonies where gulls and cormorants nest, human disturbance may result in nests being left unattended exposing their contents to predation by crows. Such predation has retarded the breeding cycle by as much as two weeks at some colonies. Disturbance may also result in territorial clashes which, for strongly territorial birds like gulls, may result in the death of chicks. Campfires, unattended or not closely watched, are always a threat to tinder-dry vegetation on colonies in the Strait of Georgia and Juan de Fuca Strait. Refuse such as string, wire and bits of metal left by visitors can often result in slow death to adults and young through entanglement or, if ingested, internal hemorrhaging.

A growing threat to sea-birds is the increased use of ocean by man as a common sink in which to dump substances like oil, sewage, toxic chemicals and nuclear wastes. Of all forms of marine pollution oil is probably the most serious and potentially the greatest threat to sea-birds. Ironically, the current awareness of the kinds and numbers of sea-birds results from the exposure the media has given to the effects major oil spills have had on sea-

birds in Europe and the United States.

Brandt's and Pelagic Cormorants now must share their sea with the commerce of man.

There are many sources of oil pollution. They include seepage or blowouts from offshore drillings and mining installations, rupture of terrestrial and submarine gas and oil pipelines, casualties from vessels carrying cargo or fuel oils, operational mishaps in pumping petroleum products, de-ballasting of vessels, cleaning oil tanks and pumping bilge water. Less known and frequently unrecognized sources of oil pollution are waste from gasoline service stations and municipal sewage systems which includes rain-leached oils from roads and large asphalt parking lots. There is also natural seepage of oil from the earth.

Regardless of its source, oil goes where water goes. By nature "oil on water is a seeker. Once it has encountered something solid to cling to -- whether it be a beach, a rock, a piling, the feathers of a duck or gull or a bather's hair -- it does not readily let go " (22). A spot of oil the size of a 25-cent piece, on a bird's breast, is sufficient to cause death through loss of the insulating properties of feathers. Some sea-birds may avoid oil slicks but others (e.g. murres) may be attracted to them because patches of oil on the surface of the sea may resemble schools

of small fish [21]. Just what the *total* effect "oiling" has on sea-birds is unknown. Dying or dead birds washed ashore are just a fraction of the total affected by oil pollution. Scores more slowly starve to death, or die from ingested oil from preening, and sink out of sight far at sea.

The threat of major oil spillages from tanker traffic along the British Columbia coast will become more acute, especially with completion of the Trans-Alaskan Pipeline in 1977/78. Although legislative efforts have been made to control oil pollution (e.g. Health Act, Pollution Control Act and Canada Shipping Act), it is just a matter of time before a catastrophe occurs. Despite stringent legislation more than 2,000 spills from both land- and marine-based facilities occurred in the United States in 1966 alone. Among the causes of these spills were collisions, explosions, groundings, capsizings and floodings [22]. To date, with the exception of the Panamanian freighter VANLENE which went aground in Barkley Sound, Vancouver Island, on March 14, 1972, most spills in British Columbia have been small. On that occasion more than 37,000 gallons of heavy bunker fuel fouled beaches and wildlife in the area [15]. Biologists were quick to point out that the route followed by the VANLENE was similar to that proposed for supertankers carrying oil from Alaskan to southern ports.

Human error and poor judgement cannot be excluded from consideration in devising measures to control oil pollution. Any spill, whatever the cause, in the wrong place at the wrong time, could seriously affect our sea-birds. By studying the chart on page 43, and knowing something about their biology, one could forecast what species might be affected, and how, if a major spill were to occur at some spot on Vancouver Island, especially in June and July. The two most numerous species off the northern tip of Vancouver Island, Cassin's Auklet and Rhinocerous Auklet, are both diving sea-birds and therefore would be seriously affected by oil-contaminated water. The most numerous species along the West Coast of Vancouver Island is Leach's Storm-petrel. Spending more time flying than on the water it might not be as badly affected as northern alcids. Local spills, however, could affect populations of alcids breeding on colonies such as Solander Island and Cleland Island. Gulls, the most numerous sea-bird in the Strait of Georgia, would probably be the least vulnerable to oil pullution. However, it is worth recounting that an average of 56.5

dead gulls were found per mile of shoreline after a spill from the fuel tanks of the frigate SEAGATE which was wrecked in 1956 off the Olympic Peninsula, Washington [14].

There are no simple solutions to the problems associated with oil pollution. It is an international problem and perhaps, through intelligent and constructive criticism, we can encourage government agencies to work together to reduce the impact of this threat to our coastal areas. In the meantime, marine bird biologists must act quickly to gather base-line information on the distribution, abundance and life histories of sea-birds in British Columbia. Only then can we point to sensitive links in their lives and offer constructive means of protecting them at these points.

Oil pollution, as a threat to sea-birds, has been recognized for at least 75 years. However, it is only within the last decade that another environmental pollutant has become evident, that of toxic chemicals. These include persistent and non-persistent pesticides and heavy metals which result mainly from agricultural and industrial activities. Many of these pollutants find their way into the oceans with rain, wind or silt from land. They can either kill directly or, in the long term, affect the reproductive cycle of birds, through egg-shell thinning and the poisoning of embryos. Residues of chemical pollutants have been found in wildlife throughout the world and their effects remain largely unknown. Just what levels marine birds can tolerate without affecting their livelihood is another facet of research that requires immediate attention.

Another threat, of unknown importance, is eutrophication caused by nitrates and phosphates in domestic sewage, agricultural and domestic fertilizers, and detergents. Pollution of this type results in algal blooms which in turn utilize dissolved oxygen in the water which eventually results in the death of most life forms. If eutrophication can happen to inland waters like Lake Erie, why not the vulnerable ocean as well.

Despite many threats to sea-birds, they still exist in unbelievable numbers. This may not always be the case. It is important then, to establish a long-term programme of monitoring sea-bird colonies so that changes in numbers and distribution can be determined. Ideally the census should be carried out at least every 10 years, should have a multi-disci-

plinary approach and possibly be part of an ecological survey involving marine mammals and marine-associated birds. The teams of counters should include amateurs and professionals, working together for the benefit of sea-birds. Such an undertaking involves time, knowledge, money, patience and a certain amount of adventure and danger. I would like to suggest that we pool our talents and interests and conduct the first survey of this kind in North America, along the British Columbia coast, in the summer of 1980. Only through your support, concern and response will we know "how much is a sea-bird really worth?"

* * *

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POOR

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